

EUROPEAN COMMISSION

DG MOVE

SEVENTH FRAMEWORK PROGRAMME

GC.SST.2012.2-3 GA No. 321592



Vehicle Regulations. State of the Art.

Deliverable No.	LNG-BC D4.1	
Deliverable Title	Vehicle regulations. State of the Art.	
Dissemination	Public	
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Issue date	09/12/2013	

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REVISION HISTORY

Rev	Date	Author	Organization	Description
0.1	11-11-2013	Javier LEBRATO	NGVA	Initial Draft
0.2	21-11-2013	Jaime DEL ALAMO	NGVA	General Revision
0.3	25/11/2013	Jesús GALLEGO	IDIADA	Revision
0.4	26/11/2013	Curt GANELES	ERDGAS	Comments, General Revision
0.5	29/11/2013	Jesús GALLEGO	IDIADA	Revision and addition of final contributions and commentaries

1 Introduction

1.1 What is the LNG BLUE CORRIDORS Project

The Blue Corridors project's aim is to establish LNG as a real alternative for medium & long distance transport - first as a complementary fuel and later as an adequate substitute for diesel.

Until now the common use of natural gas as fuel was only in heavy vehicles running on natural gas (NG) for municipal use, such as urban buses and garbage collection trucks. In these applications, engine performance and autonomy are good with present technologies, which are well adapted to this cleaner alternative fuel.

However, when analyzing the consumption data, the equivalence in autonomy of 1 litre of diesel oil is 5 litres of CNG, compressed to 200 bar. Five times more volume of fuel prevents the use of CNG in heavy road transport, because its volume and weight would be too great for a long-distance truck.

This opens the way for LNG (Liquefied Natural Gas), which is already the medium used to transport natural gas by ship to any point of the globe. NG liquefies at 162° C below zero, and the cost in energy is only 5% of the original gas.

This liquefied state gives LNG the advantage of very high energy content. Only 1.8 litres of LNG are needed to meet the equivalent autonomy to 1 litre of diesel oil.

A 40 ton road tractor in Europe needs a tank of 400 to 500 litres for a 1,000 km trip; its equivalent volume with liquid gas would be 700 to 900 litres of LNG, a tank dimension that could be easily fitted to the lateral of the truck chassis. LNG is therefore opening the use of NG to medium and long distance road transport.

LNG has huge potential to contribute to meeting the Commission's targets for greenhouse gas reduction and air quality, while simultaneously reducing dependency on crude oil and guaranteeing security of supply. Natural gas-powered heavy-duty vehicles already comply with Euro V emission

standards and have enormous potential to reach future Euro VI emission standards without complex exhaust gas aftertreatment technologies, thereby avoiding increased procurement and maintenance costs.

To accomplish its objective the LNG Blue Corridors project has defined a roadmap of LNG refuelling points along four corridors covering the Atlantic area (green line), the Mediterranean region (red line) and connecting Europe's South with the North (blue line) and its West and East (yellow line) accordingly. In order to implement a sustainable transport network for Europe, the project has set the goal to build 14 new LNG or L-CNG stations, both permanent and mobile, at critical locations along the Blue Corridors while building up a fleet of approximately 100 LNG-Powered Heavy-Duty Vehicles (HDVs). These vehicles will be provided by the primary manufacturers of LNG-powered HDVs including Volvo, Iveco, Daimler/Hardstaff, and Renault Trucks.

This European project is financed by the Seventh Framework Programme (FP7), with the amount of 7.96 M€ (total investments amounting to 14.33 M€), involving 27 partners from 11 countries.



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This document corresponds to the first deliverable within work package 4. It is an overview of the regulations about LNG HD. It will be available in internet through the next link: <http://www.lngbluecorridors.eu/> which can be consulted by any user. It has a public access.

1.2 Current status of Regulations affecting the construction and operation of LNG vehicles

Experience has shown that the lack of common standards within the European Union is the main obstacle for a wide deployment of heavy-duty vehicles powered by liquefied natural gas (LNG).

This report describes the state of the art of existing and forthcoming regulations and standards in the main European countries where LNG vehicles have already been placed in the market. In countries where LNG vehicles have not been introduced yet, it is usually difficult to find any legal framework directly connected to this vehicle technology.

In this regard, a new version of Regulation No 110 regarding the type-approval provisions for vehicles equipped with LNG propulsion system has been already approved and is expected that will come into force in July 2014 when Contracting Parties will also conform their national regulations to this new Regulation 110. It is not going to be possible to homologate a LNG vehicle until this happens in countries such as France and Germany, where currently there is not a national legal framework.

Even though this document covers vehicles of categories M and N with regard to the installation of specific components for the use of liquefied natural gas (LNG) in their propulsion system, the European L-NGV industry has shown experience mainly in the use of Medium & Heavy-Duty Commercial Vehicle applications (categories N2 & N3) and recently some in pilot projects with Medium and Heavy-Duty Buses (categories M2 & M3).

2 Terms and definitions

For a complete understanding of this document, some definitions have to be taken into consideration. For the sake of coherence, most of those have been aligned to already existing definitions commonly used by the European NGV industry.

Pressure

Means relative pressure versus atmospheric pressure, unless otherwise stated.

Service pressure or Operating pressure

Means the settled pressure at a uniform gas temperature of 15 °C. Service pressure for LNG means the intended settled pressure of the tank in use –as declared by the manufacturer.

Operating temperatures

Means maximum values of the temperature ranges, at which safe and good functioning of the specific component is ensured and for which it has been designed and approved.

Specific component

- Tank;
- Accessories fitted to the container;
- Pressure regulator;
- Automatic valve;
- Manual valve;
- Gas supply device;
- Gas flow adjuster;
- Rigid fuel line;
- Filling unit or receptacle;
- Non-return valve or check valve;
- Pressure relief valve (discharge valve) primary and secondary;
- Filter;

- Pressure or temperature sensor / indicator;
- Excess flow valve;
- Service valve;
- Electronic control unit;
- Gas-tight housing;
- Fitting;
- Ventilation hose;
- Fuel rail;
- Heat exchanger/vaporizer;
- Natural gas detector;
- Fuel pump for LNG.

Multi-functional component

Means any of the above-mentioned specific components combined or fitted together as a component.

Approval of a vehicle

Means the approval of a vehicle type of categories M and N with regard to its LNG system as original equipment for the use in its propulsion system.

Vehicle type

Means vehicles fitted with specific components for the use of LNG in their propulsion systems which do not differ with respect to the following conditions:

- the manufacturer,
- the type designation established by the manufacturer,
- the essential aspects of design and construction:
 - Chassis/floor pan (obvious and fundamental differences)
 - The installation of the LNG equipment (obvious and fundamental differences)

LNG system

Means an assembly of components (tanks, valves, flexible fuel lines, etc.) and connecting parts (fuel lines, fittings, etc.) fitted on motor vehicles using LNG in their propulsion system and related components up to and including the vaporizer. Other parts downstream from the vaporizer shall be considered as CNG components.

Tank (or vessel)

Means any storage system used for liquefied natural gas.

Type of tank

Means tanks that do not differ in respect of the dimensional and material characteristics

Accessories fitted to the container or tank

Means the following components (but not limited to them), either separate or combined, when fitted to the container or tank.

Manual valve

Means valve which is operated manually.

Pressure sensor/indicator

Means a pressurized device which indicates the gas or liquid pressure.

Excess flow valve

Means valve which automatically shuts off or limits, the gas flow when the flow exceeds a set design value.

Gas-tight housing

Means a device that vents gas leakage to outside the vehicle including the gas ventilation hose.

Valve

Means a device by which the flow of a fluid may be controlled.

Automatic valve

Means a valve that is not operated manually.

Non-return valve or check valve

Means an automatic valve that allows gas/fluid to flow in only one direction.

Excess flow valve (excess flow limiting device)

Means a device that automatically shuts off, or limits, the gas or liquid flow when the flow exceeds a set design value.

Manual valve

Means a manual valve rigidly fixed to the cylinder or tank.

Pressure relief valve (discharge valve)

Means a device that prevents a predetermined upstream pressure being exceeded.

Service valve

Means an isolation valve that is closed only when servicing the vehicle.

Filter

Means a protective screen that removes foreign debris from the gas or liquid stream.

Fitting

Means a connector used in a piping, tubing, or hose system.

LNG fuel pump

Means a device to establish the supply of LNG to the engine by increasing the pressure of the fluid

(liquid or vapour).

Rigid fuel lines

Means tubing that has not been designed to flex in normal operation and through which natural gas flows.

Gas supply device

Means a device for introducing gaseous fuel into the engine intake manifold (carburettor or injector).

Gas/air mixer

Means a device for mixing the gaseous fuel and intake air for the engine.

Gas injector

Means a device for introducing gaseous fuel into the engine or associated intake system.

Gas flow adjuster

Means a gas flow restricting device, installed downstream of a pressure regulator, controlling gas flow to the engine.

Pressure regulator

Means a device used to control the pressure of CNG or LNG.

Filling unit or receptacle

Means a device fitted in the vehicle used to fill the container or tank in the filling station.

Electronic control unit (LNG)

Means a device that controls the gas demand of the engine, and other engine parameters, and cuts off automatically the automatic valve, required by safety reason.

Heat exchanger/Vaporizer

Means a device used to change the state of LNG into CNG.

Liquefied Natural Gas (LNG)

Also called "Liquid Natural Gas" means a cryogenic liquid produced by reducing the temperature of natural gas to about -161.7 °C at atmospheric pressure and stored for use as a vehicle fuel.

Compressed Natural Gas (CNG)

Means natural gas that has been compressed and stored for use as a vehicle fuel.

Boil-off

Means gas created by evaporation of LNG due to ambient heat input.

Venting

Means the discharge of vapours out of the storage container/tank.

Venting system

Means a system that controls the release of natural gas from the LNG storage system.

LNG trapping

Means the containment of LNG in an enclosure of constant volume.

Cryogenic temperature

Means temperatures below -40 °C.

Inner vessel or inner tank

Means part of the fuel tank that contains LNG.

Outer vessel or outer jacket

Means part of the fuel tank that encases the inner vessel or inner tank(s) and its insulation system.

Fuel rail

Means the pipe or duct that connects the fuel injection devices.

LNG nozzle

Means device which permits quick connection and disconnection of fuel supply hose to the LNG receptacle in a safe manner.

LNG filling receptacle

Means device connected to a vehicle or storage system which receives the LNG fuelling nozzle and permits safe transfer of fuel. The receptacle consists as minimum of a receptacle body and of a check valve mounted inside the body.

3 Abbreviations

°C	degrees Celsius
CNG	Compressed Natural Gas
ECU	Electronic Computer Unit
HDV	Heavy-Duty Vehicles
LCNG	Compressed Natural Gas, sourced from LNG
LNG	Liquefied Natural Gas
OEM	Original Equipment Manufacturer

4 LNG vehicles regulations & standards

4.1 General framework in Europe

The document's aim is to give an overview regarding the regulations and standards implicated in each country and affecting the construction and homologation of heavy-duty vehicles powered by liquefied natural gas. As such, the main aspects covered in this analysis are linked with safety, though some minor environmental issues are also referenced.

In first place, it is to be noted that experience with LNG heavy-duty vehicles has come after years of experience with CNG vehicles, thus all regulations and standards affecting the construction and approval of specific LNG components have been developed taking into consideration the already existing legal framework for CNG vehicles and their components.

Up to now, all on-board CNG related aspects were approved according to ECE Regulation 110, but LNG was missing in its scope. Thus the Heavy-Duty vehicle manufacturers have been experiencing certain issues regarding the deployment of L-NGVs in most European markets, where they have had to rely on national approvals to-date. This has certainly set a barrier as those vehicles were only recognized by those countries granting the approval, causing problems for most fleet operators willing to travel across the European Union.

After years of experience in the use of this vehicle technology, the European NGV industry addressed the need to solve the above-mentioned lack of harmonization, and this was partially carried out through the work of the UNECE LNG Task Force. This Task Force, with the cooperation of several European LNG vehicle and component manufacturers, has worked for more than two years to update ECE R110 in order to include all the necessary amendments for LNG components & systems to be approved.

As previously mentioned, and due to the fact that ECE R110 focus is for on-board vehicle equipment, aspects assuring the proper connection between the vehicle and the filling station are something typically dealt between the Regulation 110 and the filling station equipment

requirements (for nozzles specially). This aspect was years ago solved for CNG vehicles by the establishment of two standardised sets of nozzles and receptacles:

NGV1: typical for light-duty CNG vehicles, designed and manufactured according to ISO 14469:

20 MPa filling unit (receptacle) for M₁ and N₁ vehicles

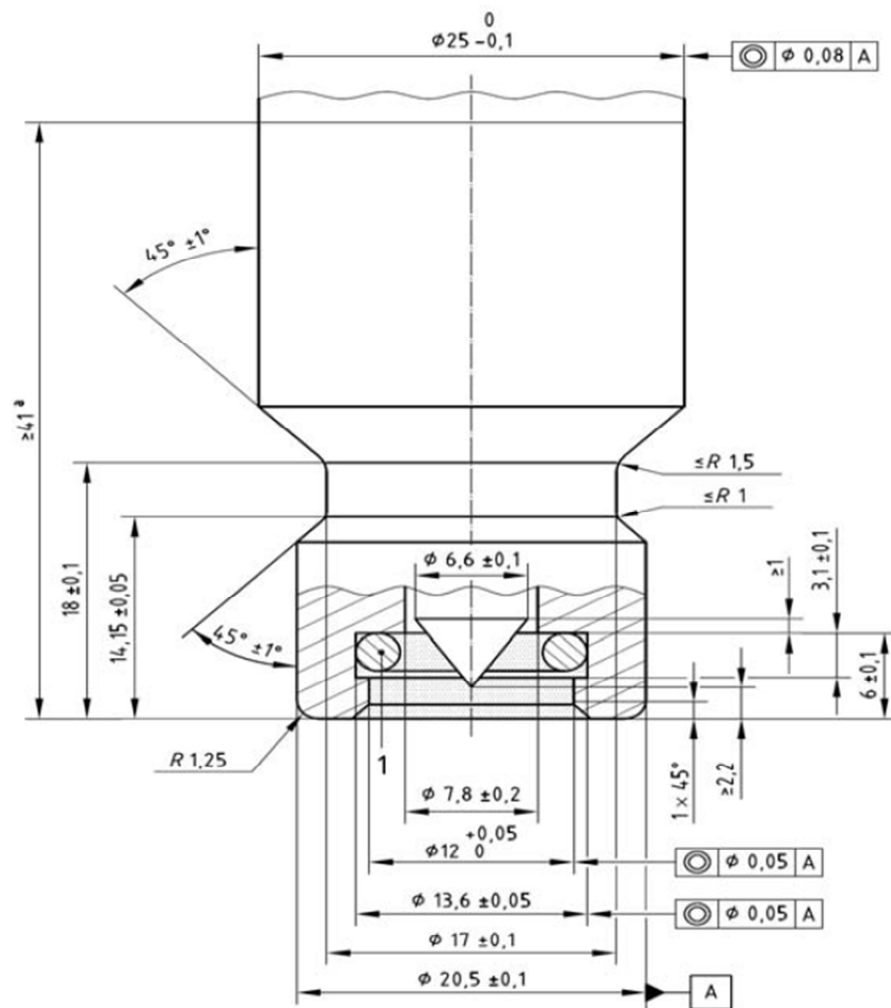


Figure 4-1 Receptacle for M₁ and N₁ vehicles

NGV2: typical for heavy-duty CNG vehicles, designed and manufactures according to ISO 14469:

20 MPa Filling unit Size 2 (receptacle) for M₂, M₃, N₂ and N₃ vehicles

Dimensions in millimetres

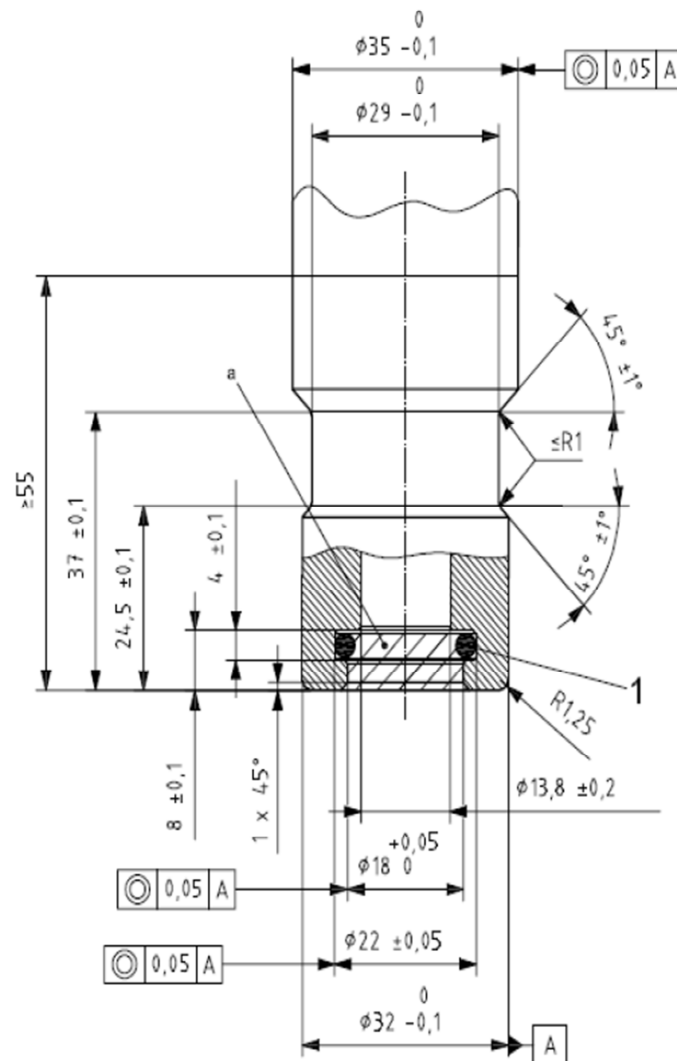


Figure 4-2 Receptacle for M2, M3 N2 and N3 vehicles

There are several approaches concerning the design and operation of LNG filling units. This has made it impossible for the LNG Task Force to establish a given standardised size of the LNG nozzle-receptacle. This challenge is evidenced by the unfinished standardisation work being carried out at international level by the ISO Technical Committee 22 (Road Vehicles) Sub-Committee 25 (Vehicles Using Gaseous Fuels), which has been working for the last years on the preparation of ISO/DIS

12617 - LNG Connector for Refuelling Vehicles.

This standard is already approved and will come into force in July 2014 when Contracting Parties will also conform their national regulations to the new R.110 Regulation, incorporating the design specifications (mating dimensions, geometry and tolerances, material requirements, etc) for LNG nozzles and receptacles to be submitted for certification.

Between many other requirements, it states that both components have to be:

- Designed to minimize the possibility of an incorrect assembly
- Designed to be secure against displacement, distortion, warping or other damage
- Constructed to maintain operational integrity
- Designed to prevent spillage in excess of 30 cm³ during disconnection

The initial intention of the stakeholders involved in the development of the ECE R110 was to update the requirements contained in it as soon as the ISO/DIS 12617 got approved. Until then, depending on the L-NGV manufacturer, differences in design could occur, creating potential compatibility issues.

4.2 General framework in the U.S.

As with Europe, the experience with L-NGVs in the US market was borne from experiences gathered with the use of CNG. Nevertheless, the US possesses broader experience in the use of LNG, probably due to the substantial changes in the energy sector caused by the shale gas era.

Currently, the main legal framework for CNG and LNG components/systems approvals is based on the US National Fire Protection Association (NFPA) Code N. 52 on Vehicular Gaseous Fuel Systems Code (first edition in 1998, last edition in 2013), the US National Fire Protection Association (NFPA) Code N. 57 on LNG Vehicular Fuel Systems (2002), The Society of Automotive Engineers (SAE) Standard J2343 on Recommended Practices for LNG Medium and Heavy-Duty Powered Vehicles, the Code of Federal Regulations (CFR) N. 49 Subpart 178.57 and Subpart 393-E on Welded Insulated Cylinders, and Fuel Systems respectively, the Compressed Gas Association (CGA) Standard 1. 1-2 on Cylinders for Compressed Gases and on Cargo and Portable Tanks for Compressed Gases. In addition to this, the ISO/TC 22/SC 25 has also worked during the last years in the preparation of the

ISO 12991 on LNG Tanks for on-board storage as a fuel for automotive vehicles.

While compressed natural gas (CNG) vehicles have been used extensively in other countries since the late 1940s, it was not until the late 1970s that their use in the United States became extensive enough to warrant preparation of a national standard.

Between 1980 and 1982, a committee of the American Gas Association (AGA) developed a draft of a fire safety standard for vehicular fuel systems. This was based on existing worldwide standards and current U.S. practice.

In late 1981, the AGA petitioned the NFPA to establish a technical committee project on the subject. The normal NFPA solicitation of comments revealed sufficient response from various interested parties, and the Committee on Compressed Natural Gas Vehicular Fuel Systems was established by the Standards Council in July 1982.

The first edition of NFPA 52 was issued in 1984, and it was revised in 1988, 1992, 1995, and 1998.

The 2006 edition of NFPA 52 is a complete revision. NFPA 57 (LNG Vehicular Fuel System Code shall apply to the design, installation, operation and maintenance of liquefied natural gas fuel systems on vehicles of all types, to their associated fuelling (dispensing) facilities, and to LNG to CNG facilities with LNG storage in ASME containers of 70.000 gal (265 m³) or less), has been incorporated into NFPA 52.

As previously commented, at the same time, SAE J2343 is applied in the US. Its purpose is to promote safety and efficiency by making available to sellers and buyers of commercial liquefied natural gas-powered medium and heavy-duty vehicles a recommended practice for construction, operation and maintenance of such vehicles.

4.3 Current European L-NGV Markets and Main Actors

Even if, in some EU countries, the experience with LNG vehicles started quite some years ago via the conversion of existing diesel trucks to run on dual-fuel (diesel plus NG) mode, it has not been until 4-5 years ago that European OEMs officially jumped into the HD LNG vehicle business by offering

ex-factory LNG models. These are the main examples nowadays:

OEMs. LNG trucks directly produced from the factory:

- Iveco: with dedicated spark ignited engines, working with 100% natural gas. 330 Hp. Chart LNG tank technology.
- Volvo: Dual-fuel compression ignition engines, working with diesel-NG blends of around 70% NG. 460 Hp. Chart LNG tank technology.
- Mercedes: Dedicated spark ignited engines. 280 Hp, use an Indox LNG tank technology.
- Scania: Dedicated spark ignited engines, working with 100% natural gas. 305 Hp. Indox LNG tank technology.

Adaptations. LNG trucks transformed once they leave factory:

- Hardstaff: Involved in the use of dual-fuel technology in heavy road haulage vehicles in the UK and Europe.
- Clean air power: Their technology allows the diesel engine to run on Diesel and natural gas simultaneously with an average substitution rate of up to 60%.
- HAM Transports: Their main aim is the transport by road of liquefied gases only transportable by special vehicles. They have adapted more than 70 vehicles.
- Prins Autogas: They have developed an innovative range of core components for delivering CNG/ LNG to electronic multi-point gas injection systems in heavy-duty vehicle applications for OEM and aftermarket customers.

Figure 4-1 shows the total population of LNG trucks sold (from OEM and converted) in each European country.

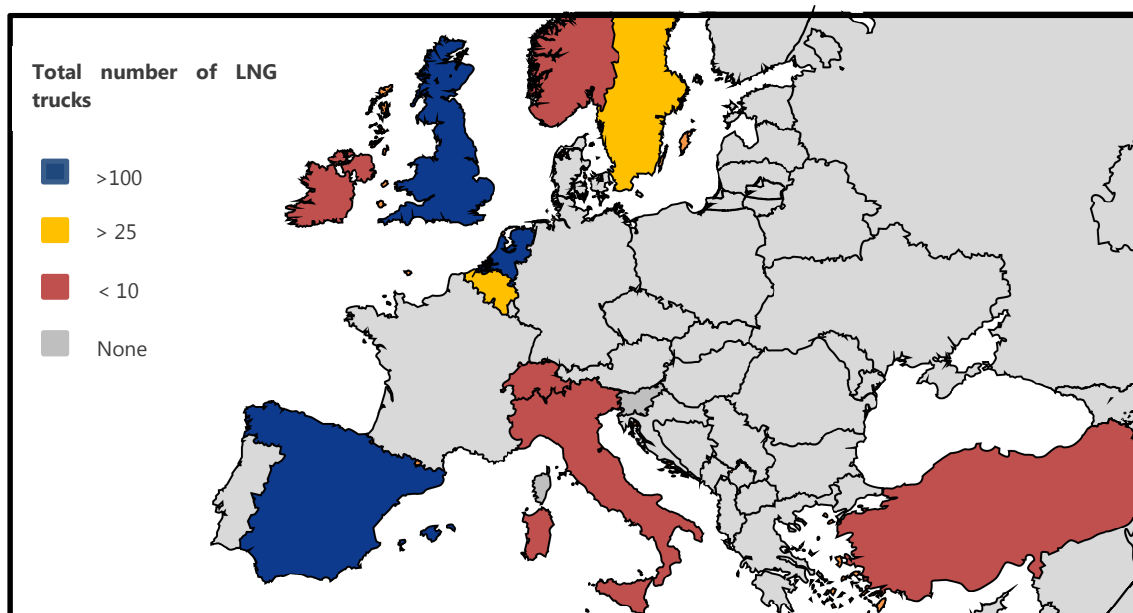


Figure 4-3 LNG Trucks per country, including original and converted.

4.4 Summary of national requirements for different European countries

It is important to consider that an LNG on-board fuel system is not so different from a CNG one. The reason behind the use of liquefied natural gas instead of compressed natural gas is the higher energy density of the first one, making it possible to store more energy in a given storage volume via LNG than with CNG.

In fact, the engines installed in both CNG and LNG vehicles are finally fed by natural gas in gaseous state. Once the fuel leaves the cryogenic storage tank (on demand by the engine), it enters the heat exchanger/vaporizer and then heads to the pressure regulator, where its pressure conditions are adapted to those required by the engine inlet. The diagram below describes in general terms the main devices involved in both technologies: LNG technology on the left side and CNG technology in the right side.

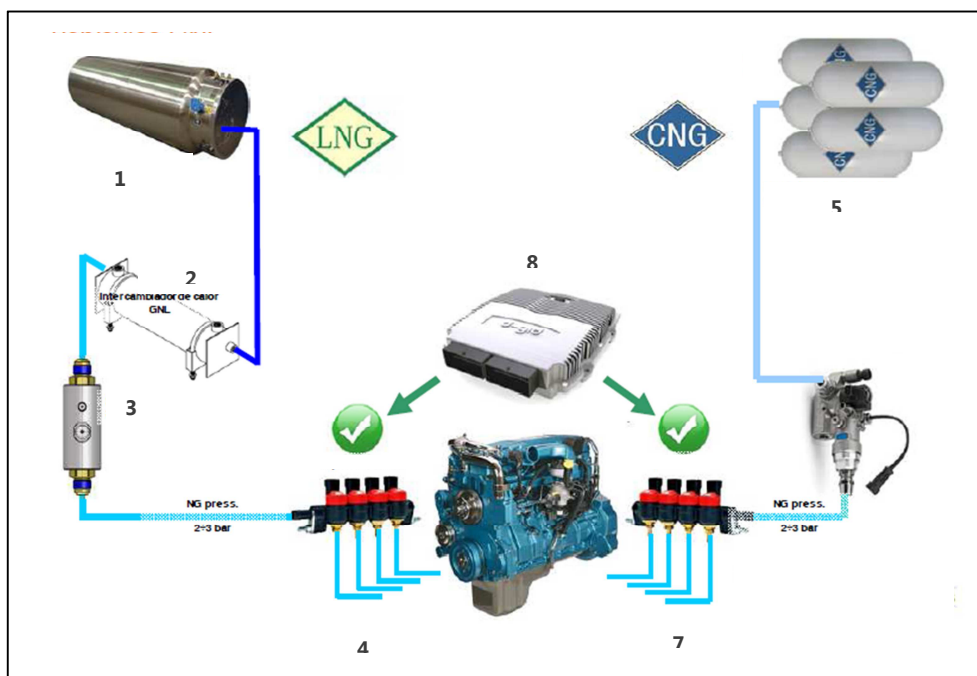


Figure 4-4 Comparison between LNG and CNG components. Source: IDIADA

1. Cryogenic tank. -120°C at 11 bar.
2. Heat exchanger LNG (in some cases it is inside the tank).
3. Pressure regulator. Output at 5-8 bar.
4. NG injectors.
5. High pressure tank. CNG at 200 bar.
6. Pressure regulator. Input at 200 bar. Output at 5-8 bar.
7. NG injectors.
8. ECU.

As described above, only a few elements within the fuel system are different for LNG compared to CNG vehicles. The state, i.e. pressure and temperature, in the injectors is the same. The main difference is the natural gas state at output of the tank. Once the natural gas leaves the cryogenic tank, it goes to the pressure regulator, across a heat exchanger in the case of LNG system. That exchanger increases its temperature.

Exclusively those specific devices from LNG system will be analysed in this document. The rest of elements meet international CNG regulation in this respect (ECE regulation 110).

Based on the information mentioned in the last point, the following countries have been considered

(arranged by number of vehicles sold).

4.4.1 Spain

Fuel tank

Must meet the requirements outlined in standard UNE EN 1251:2001 (Cryogenic vessels - Transportable vacuum-insulated vessels of not more than 1000 litres volume). In some cases, if the security of the system is proved special instructions based on this standard or NFPA 57 (Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code) are allowed.

Valves

Valves included in the tank must fulfil the requirements established in UNE EN 1251. Previously was demanded the national regulation described in the *Real Decreto* regarding equipment under pressure.

Receptacle

It must be of Kodiak type.

Heat exchanger

It must be associated to the tank or without exit.

Pressure regulator

Installation according to R110.

Piping

Must fulfil the R110 requirements.

Valves

Valves included in the system need to fulfil the R110.

NG detector

Not required.

Sensors

According to R110.

Other LNG-specific components

Tank + vaporizer. It is necessary to install an automatic valve in the vaporizer.

Abstract

R110; R 115; R 67; UNE EN 1251:2001; ISO 12614; ISO 12617 and SAE J2343.

4.4.2 Sweden

Fuel tank

Must meet the requirements outlined in Regulation R110 (In dual vehicles, the diesel tank must fulfil R34).

Valves

According to R110.

Receptacle

According to R110.

Heat exchanger

According to R110.

Pressure regulator

According to R110.

Piping

According to R110.

Valves

According to R110.

NG detector

According to R110.

Sensors

According to R110.

Other LNG-specific components

Prevention of fire according to R 110.

National requirements for Periodical Technical Inspection (minimum content harmonized in 2009/40/EC).

Pollution emissions regarding R49, EURO VI.

Noise pollution regarding 70/157/EEC or ECE R51.

Abstract

R110, R115, R34, R49, R51, 70/157/EEC.

4.4.3 The Netherlands

Fuel tank

Those are not specifically tested as, in the past, LNG tanks from the two main manufacturers there (Chart + Indox) were exhaustively tested according to the Transportable Pressure Equipment Directive.

Receptacle

The connection of the tank to the vehicle is tested based on the G forces mentioned in the R110.

Piping

Low temperature test in case of non-metallic fuel lines.

Valves

The PRV's (Pressure relief valve) need to comply with the R110 or ISO15500 tests.

NG detector

Natural gas detectors (for potential natural gas leakages) are checked according to R110 ECU and to evaluation by a technician.

Sensors

ECU signals for pressure sensors and fuel gauge are checked according to R110 ECU and to evaluation by a technician.

Other LNG-specific components

The manufacturer of the Vaporizer must prove that the system does not break in case of gas leak.

In The Netherlands there were no other regulations or drafts available other than the R110. So R110 and the PED are the most used documents in combination with the R115 for the vehicle evaluation (component safety according to R110, building instructions user manual etc. according to R115, emission and powertrain according to the R115 mentioned regulations)

Abstract

R110, ISO15500, PED, R115 and the technical knowledge by the test departments involved.

4.4.4 United Kingdom

No special requirements are required in the United Kingdom for the different components.

Fuel tank

Must meet the requirements outlined in Regulation R110 (In dual vehicles, the diesel tank must fulfil R34).

4.5 Summary of regulations in force

4.5.1 International standards

ISO 12991:2012 • Liquefied natural gas (LNG) – Tanks for on-board storage as a fuel for automotive vehicles

Status: international standard published

Abstract: ISO 12991:2012 specifies the construction requirements for refillable fuel tanks for liquefied natural gas (LNG) used in vehicles as well as the testing methods required to ensure that a reasonable level of protection from loss of life and property resulting from fire and explosion is provided. It is applicable to fuel tanks intended to be permanently attached to land vehicles but can be used as a guide for other modes of transport.

Other related standards: ISO 13984, ISO 21029-1, ISO 21011, ISO 21013-1, ISO 13985.

ISO 15500 and ISO 15501 series (from 15500-1 to 15500-20 and 15501-1 to 15501-2) • Road vehicles – Compressed natural gas (CNG) fuel system components and fuel systems

Status: international standard published, but some parts currently in revision and/or under development by ISO/TC 22/SC 25.

Note: For LNG vehicles, these standards apply to the components installed downstream from the vaporizer.

ISO 15500 • Road vehicles – Compressed natural gas (CNG) fuel system components

Part 1: General requirements and definitions (ISO 15500-1:2000, ISO 15500-1:2000/Amd 1:2003 and ISO/WD 15500-1)

Part 2: Performance and general test methods (ISO 15500-2:2012)

Part 3: Check valve (ISO 15500-3:2012)

Part 4: Manual valve (ISO 15500-4:2012)

Part 5: Manual cylinder valve (ISO 15500-5:2012)

Part 6: Automatic valve (ISO 15500-6:2012)

Part 7: Gas injector (ISO 15500-7:2002 and ISO/WD 15500-7)

Part 8: Pressure indicator (ISO 15500-8:2001 and ISO/WD 15500-8)

Part 9: Pressure regulator (ISO 15500-9:2012)

Part 10: Gas flow adjuster (ISO 15500-10:2001 and ISO/WD 15500-10)

Part 11: Gas/air mixer (ISO 15500-11:2001 and ISO/WD 15500-11)

Part 12: Pressure relief valve (PRV) (ISO 15500-12:2001 and ISO/WD 15500-12)

Part 13: Pressure relief device (PRD) (ISO 15500-13:2012)

Part 14: Excess flow valve (ISO 15500-14:2012)

Part 15: Gas-tight housing and ventilation hose (ISO 15500-15:2001 and ISO/WD 15500-15)

Part 16: Rigid fuel line in stainless steel (ISO 15500-16:2012)

Part 17: Flexible fuel line (ISO 15500-17:2012)

Part 18: Filter (ISO 15500-18:2012)

Part 19: Fittings (ISO 15500-19:2012)

Part 20: Rigid fuel line in material other than stainless steel (ISO 15500-20:2007 and ISO/WD 15500-

20)

ISO 15501 • Road vehicles – Compressed natural gas (CNG) fuel systems

Part 1: Safety requirements (ISO 15501-1:2012)

Part 2: Test methods (ISO 15501-2:2001)

ISO 21014:2006 → Cryogenic vessels – Cryogenic insulation performance.

Stage: international standard published.

Abstract: defines practical methods for determining the heat-leak performance of cryogenic vessels. The methods include measurement on both open and closed systems. It neither specifies the requirement levels for insulation performance nor when the defined methods should be applied. These requirements may be defined in design or operational standards/regulations.

ISO 21009:2006/2008 → Cryogenic vessels – Static vacuum-insulated vessels.

Stage: international standard published.

It specifies requirements for the design, fabrication, inspection and testing of static vacuum-insulated cryogenic vessels designed for a maximum allowable pressure of more than 0.5 bar.

Specifies operational requirements for static vacuum-insulated vessels designed for a maximum allowable pressure of more than 0.5 bar (50 kPa). It may also be used as a guideline for vessels designed for a maximum allowable pressure of less than 0.5 bar (50 kPa).

4.5.2 European standards

A. Engine emissions regulations for LNG HDVs

UNECE R.49 regulates engine emissions for heavy-duty vehicles. The emissions from positive-ignition (PI) engines fuelled with natural gas were included in UNECE R.49 rev. 5¹, which latest amendments entered into force on July 26, 2012. Heavy duty dual-fuel vehicles and engines have now been included in the UNECE R.49 rev. 6² regulation for the first time. This revision of the R.49 regulation first entered into force on January 27, 2013 and an amendment was introduced on July 15, 2013. All new Euro VI LNG HDVs are therefore now covered by the R.49 regulation.

EN1251-2:2000 → Cryogenic vessels. Transportable vacuum-insulated vessels of not more than 1000 litres volume. Design, fabrication, inspection and testing.

Status: European Standard published (15/05/00)

Content:

- Part 1: fundamental requirements.
- Part 2: design, fabrication, inspection and testing.
- Part 3: operational requirements.

Description: Cryogenic equipment, Cryogenics, Pressure vessels, Transportable, Vacuum insulation, Volume, Design, Inspection, Approval testing, Non-destructive testing, Radiographic testing, Surfaces, Defects, Stress analysis, Elastic deformation, Welding, Flammable material.

Cross references: BS 5500:1997, CODAP 1995, EN287-1, EN287-2, EN288-3, EN288-4, EN288-8, EN473, EN729-2, EN729-3, EN895, EN910, EN962, EN970, EN1251-1, EN1251-3, EN1252-1, EN1418, EN1435, EN1626, EN1708-1, EN1797-1, EN10045-1, EN10204, EN12213, EN12.

¹ <http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R049r5e.pdf> and <http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R049r5am2e.pdf>

² <http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2013/R049r6e.pdf> and <http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2013/R049r6am1e.pdf>

UK DOT-4L (HSE, 1999) → Welded insulated cylinders. This standard provides a complete set of specifications for welded insulated cylinders.

1999/36/EC → Transportable Pressure Equipment Directive.

The purpose of this Directive is to enhance safety with regard to transportable pressure equipment of dangerous goods by road.

4.6 Summary regulation ongoing

4.6.1 ECE R110

As mentioned above, ECE R110 has been updated in order to include the requirements for LNG components. The proposal has been prepared as a new consolidated version (Revision 3) of UN Regulation No. 110. A summary is explained following.

PART I – APPROVAL OF SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUEFIED NATURAL GAS (LNG) IN THEIR PROPULSION SYSTEM.

- **Markings**

The sample of specific component or multifunctional components submitted for approval shall bear the trade name or mark of the manufacturer and the type, including one concerning designation on operating temperatures ("M" or "C" for moderate or cold temperatures "L" for LNG as appropriate).

Every tank shall also bear a marking plate with the following data clearly legible and indelible:

- a) Serial number.
- b) Gross capacity in litres.
- c) The marking "LNG".
- d) Service pressure/Working pressure [MPa].
- e) Mass (kg).
- f) Manufacturer.
- g) Year and month of approval (e.g. 96/01).
- h) The marking "PUMP INSIDE, Pump Delivery Pressure *** MPa" if the LNG fuel pump is

mounted on the tank; where the *** is the value of the pump delivery pressure.

All them shall be conspicuously affixed in the space destined.

- **Approval**

If the LNG components samples submitted for approval meet the following requirements, approval of the type of component shall be granted. These are:

- The LNG tanks shall be type approved pursuant to the provisions laid down in Annex 3B (see annex section).
- A system shall be provided for preventing the fuel tank from being overfilled.
- Provisions on components fitted to the LNG tank.
- The LNG tank shall be equipped at least with the following components, which may be either separate or combined: Pressure relief valve, manual valve and excess flow device.
- The tank may be equipped with a gas-tight housing, if necessary.
- The components: pressure relief valve, manual valve and excess flow device, shall be type approved pursuant to the provisions laid down in Annex 4 (see annex section).
- Provisions regarding other LNG components.

The components shown shall be type approved pursuant to the provisions laid down in the annexes which can be determined from the table below:

Component	Annex (see annex section)
LNG heat exchanger – vaporizer	4I
LNG filling receptacle	4J
Pressure control regulator	4K
LNG Pressure and/or temperature sensor/indicator	4L
Natural gas detector	4M
Automatic valve, check valve, the pressure relief valve, excess	4N

flow valve, manual valve and non-return valve.	
Fuel pump	40

- **Specification on LNG components**

The materials of the components that are in contact with LNG shall be compatible with them (see Annex 5D in annex section).

Those parts of components whose correct and safe functioning is liable to be influenced by LNG, high pressure or vibrations have to be submitted to relevant test procedures described in the annexes mentioned.

PART II – APPROVAL OF VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS OF AN APPROVED TYPE FOR THE USE OF LIQUEFIED NATURAL GAS (LNG) IN THEIR PROPULSION SYSTEM.

- **Application for approval**

The application for approval of a vehicle type with regard to the installation of specific components for the use of liquefied natural gas (LNG) in its propulsion system shall be submitted by the vehicle manufacturer or by his duly accredited representative. This application will be submitted beside the documentation required, in this case, Annex 1B. This annex is shown in details in the original ECE R110 document.

- **Approval**

An approval number shall be assigned to each type of vehicle approved. Its first two digits shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval.

If the vehicle submitted for approval pursuant to this Regulation is provided with all the necessary specific components for the use of liquefied natural gas (LNG) in its propulsion system meets the requirements of explained below, approval of that vehicle type shall be granted. These requirements

are:

- General

The LNG system of the vehicle shall function in a good and safe manner at the working pressure and operating temperatures for which it has been designed and approved.

All components of the system shall be type approved as individual parts or multifunctional parts pursuant to Part I mentioned above.

Notwithstanding the provisions mentioned, no separate type approval of the LNG electronic control unit is required if the LNG electronic control unit is integrated into the engine electronic control unit and is covered with a vehicle installation type approval according to Part II of this document and to Regulation No. 10 (it is about electromagnetic compatibility). The vehicle type approval shall also be pursuant to the applicable provisions laid down in Annex 4H (see annex section) of this Regulation.

The materials used in the system shall be suitable for use with LNG as applicable. All components of the system shall be fastened in a proper way.

The LNG system shall be pressurized at the working pressure and tested for leakage with a surface active agent without formation of bubbles for three minutes or by using a demonstrated equivalent method.

The LNG system shall be installed such that it has the best possible protection against damage, such as damage due to moving vehicle components, collision, grit or due to the loading or unloading of the vehicle or the shifting of those loads.

No appliances shall be connected to the LNG system other than those strictly required for the proper operation of the engine of the motor vehicle. With this regard, vehicles may be fitted with a heating system to heat the passenger compartment and/or the load area which is connected to the LNG system.

The heating system referred shall be permitted if, in the view of the Technical Services responsible for conducting type approval, the heating system is adequately protected and the required

operation of the normal LNG system is not affected.

- Identification of LNG fuelled vehicles

Vehicles of categories M2 and M3 equipped with a LNG system shall be labelled as specified in Annex 7 (see annex section).

The label shall be installed on the front and rear of the vehicle of category M2 or M3 and on the outside of the doors on the right-hand side (left-hand drive vehicles), left-hand side (right-hand drive vehicles). A label shall be placed adjacent to the LNG fill receptacle stating the fuelling requirements. The fuelling requirements shall be as recommended by the manufacturer.

- Further requirements

No component of the CNG and/or LNG system, including any protective materials which form part of such components, shall project beyond the outline of the vehicle, with the exception of the filling unit if this does not project more than 10 mm beyond its point of attachment.

Proper shielding against heat of adjacent components shall be considered and no component of the CNG and/or LNG system shall be located within 100 mm of the exhaust or similar heat source, unless such components are adequately shielded against heat.

- Installation of the container and/or tanks

The container and/or tank shall be permanently installed in the vehicle and shall not be installed in the engine compartment.

The container and/or tank shall be installed such that there is no metal to metal contact, with the exception of the fixing points of the container(s) and/or tank(s).

When the vehicle is ready for use the fuel container and/or tank shall not be less than 200 mm above the road surface. This provisions shall not apply if the container and/or tank is adequately protected, at the front and the sides and no part of the container is located lower than this

protective structure.

The fuel container(s) and/or tank(s) shall be mounted and fixed so that the following accelerations can be absorbed (without damage occurring) when the container(s) and/or tank(s) are full:

Vehicles of categories M1 and N1:

- a) 20 g in the direction of travel.
- b) 8 g horizontally perpendicular to the direction of travel.

Vehicles of categories M2 and N2:

- a) 10 g in the direction of travel;
- b) 5 g horizontally perpendicular to the direction of travel.

Vehicles of categories M3 and N3:

- a) 6.6 g in the direction of travel;
- b) 5 g horizontally perpendicular to the direction of travel.

A calculation method can be used instead of practical testing if its equivalence can be demonstrated by the applicant for approval to the satisfaction of the Technical Service.

- Accessories fitted to the LNG tanks

Excess flow valve

The excess flow valve can be fitted inside or directly on the LNG tank (in a protected position).

Pressure relief valve (primary)

The primary pressure relief valve outlet shall be connected to an open ended pipe-away system to move vented gas away to a high level. Consideration shall be given to preventing any blockage or freezing of the pipe-away. The LNG primary relief valve shall not vent into the gas-tight housing (if fitted).

Pressure relief valve (secondary)

The secondary relief valve may relieve gas immediately from its outlet. Protection from water ingress and damage shall be considered. The secondary relief valve outlet shall not be connected to the same pipe-away as the primary relief valve. The LNG secondary relief valve shall not vent into the

Gas-tight housing (if fitted).

Manual fuel shut off valve

The manual fuel shut off valve shall be mounted directly on the LNG tank (in a protected position). It should be readily accessible.

Manual vapour shut-off valve

The manual vapour shut-off valve shall be mounted directly on the LNG tank (in a protected position). It should be readily accessible.

Vent line or connector

The vent line or connector may be mounted inside or on the LNG tank (in a protected position). It should be readily accessible. The vent connector shall be suitable for the purpose at temperatures indicated in Annex 50 (see annex section) for the working pressure of the LNG tank.

Venting management system

The primary pressure relief valve shall be piped to a vent stack which extends to a high level. The primary and secondary relief valve outlets shall be protected by from fouling by dirt, debris, snow, ice and/or water. The vent stack shall be sized to prevent flow restriction due to pressure drop. Gas exiting the vent stack or secondary relieve valve shall not impinge on enclosed areas, other vehicles, exterior-mounted systems with air intake (i.e. air-conditioning systems), engine intakes, or engine exhaust. In the case of dual tanks, the primary relief valve outlets piping for each tank may be manifold to a common stack.

- Rigid and flexible fuel lines

LNG rigid fuel lines shall be made of austenitic stainless steel or copper, either seamless or welded. The LNG rigid fuel line may be replaced by a flexible fuel line if used in Class 5.

They shall be secured such that they shall not be subjected to vibration or stresses. At the fixing point, the fuel line, flexible or rigid, shall be fitted in such a way that there is no metal to metal contact.

Rigid and flexible fuel gas line shall not be located at jacking points. At passages the fuel lines shall be fitted with protective material. LNG fuel line shall be insulated or protected in those areas where low temperature can damage other components and/or harm people.

- Fitting or gas connections between the components

Soldered joints and bite-type compression joints are not permitted for CNG. Bite-type compression joints are not permitted for LNG.

Stainless steel tubes shall only be joined by stainless steel fittings.

Rigid fuel lines shall be connected by appropriate joints, for example, two part compression joints in steel tubes and joints with olives tapered on both sides.

The number of joints shall be limited to a minimum. Any joints shall be made in locations where access is possible for inspection.

In a passenger compartment or enclosed luggage compartment the fuel lines shall be no longer than reasonably required, and in any case shall be protected by a gas-tight housing.

They shall not apply to vehicles of categories M2 or M3 where the fuel lines and connections are fitted with a sleeve that is resistant against CNG and that has an open connection to the atmosphere.

- Automatic valve

An automatic valve shall be installed as close as practicable after the vaporizer in the LNG system.

- Filling unit or receptacle

The filling unit shall be secured against rotation and shall be protected against dirt and water. When the LNG container or tank is installed in the passenger compartment or an enclosed (luggage) compartment the filling unit shall be located at the outside of the vehicle or in engine compartment.

- Fuel selection system and electrical installation

The electrical components of the LNG system shall be protected against overloads.

Vehicles with more than one fuel system shall have a fuel selection system to ensure that no more than one fuel at the same time is supplied to the engine for a limited duration. "Dual-fuel" vehicles, using diesel as the primary fuel for igniting the air/gas mixture, are allowed in cases where these engines and vehicles meet mandatory emission standards.

The electrical connections and components in the gas-tight housing shall be constructed such that no sparks are generated. The LNG system shall be designed to prevent any LNG trapping.

The LNG system in category M vehicles shall be equipped with a natural gas detector and/or gas-tight housing. The LNG system in category N vehicles may be equipped with a natural gas detector if the fuel storage tank and associated piping is mounted on the exterior of the vehicle without the possibility of gas trapping. If the fuel storage tank is located inside the cargo area of a category N vehicle then a natural gas detector and/or gas-tight housing is mandatory.

PART III – ANNEXES

All those annexes referenced above, keep the original reference from the ECE R110. All these annexes are summarized following:

- **Annex 3B. Liquid tanks - Vacuum-insulated vessels for the on-board storage of natural gas as a fuel for automotive vehicles.**

This annex sets out minimum requirements for refillable liquid tanks. The tanks are intended only for

the on-board storage of liquid natural gas as a fuel for automotive vehicles to which the tanks are to be fixed. Tanks shall be of any austenitic stainless steel material, design or method of manufacture suitable for the specified service conditions.

This annex is based upon a working pressure less than 26 MPa.

Service conditions

Standard service conditions

The standard service conditions specified in this section are provided as a basis for the design, manufacture, inspection, testing, and approval of tanks that are to be mounted permanently on vehicles and used to store natural gas at cryogenic temperatures for use as a fuel on vehicles.

Use of tanks

The service conditions specified are also intended to provide information on how tanks made to this Regulation may safely be used to:

- a) manufacturers of tanks;
- b) owners of tanks;
- c) designers or contractors responsible for the installation of tanks;
- d) designers or owners of equipment used to refuel vehicle tanks;
- e) suppliers of natural gas; and
- f) regulatory authorities who have jurisdiction over tank use.

Periodic requalification

Recommendations for periodic requalification by visual inspection or testing during the service life shall be provided by the tank manufacturer on the basis of use under service conditions specified herein. Each tank shall be visually inspected at least every 120 months after the date of its entry into service on the vehicle (vehicle registration), and at the time of any reinstallation, for external damage and deterioration, including under the support straps. The visual inspection shall be performed by a Technical Service designated or recognized by the Type-Approval Authority, in accordance with the

manufacturer's specifications: tanks without label containing mandatory information, or with labels containing mandatory information that are illegible in any way shall be removed from service. If the tank can be positively identified by manufacturer and serial number, a replacement label may be applied, allowing the tank to remain in service.

Tanks involved in collisions

Tanks that have been involved in a vehicle collision shall be reinspected by an agency authorized by the manufacturer, unless otherwise directed by the Competent Authority having jurisdiction. Tanks that have not experienced any impact damage from the collision may be returned to service, otherwise the tank shall be returned to the manufacturer for evaluation.

Tanks involved in fires

Tanks that have been subject to the action of fire shall be reinspected by an agency authorized by the manufacturer, or condemned and removed from service.

Maximum pressure

The maximum allowable working pressure (MAWP) shall be defined by the manufacturer and correspond to the nominal primary relief valve setting. The maximum allowable working pressure shall be less than 26 MPa.

Temperature range

Temperature of liquid in tanks may vary from a minimum of -195 °C to a maximum of 65 °C.

Gas composition

Hydrogen shall be limited to 2 per cent by volume when tanks are manufactured from steel with an ultimate tensile strength exceeding 950 MPa.

External surfaces

Tanks are not designed for continuous exposure to mechanical or chemical attack, e.g. leakage from

cargo that may be carried on vehicles or severe abrasion damage from road conditions, and shall comply with recognized installation standards. However, tank external surfaces may be inadvertently exposed to:

- a) solvents, acids and alkalis, fertilizers; and
- b) automotive fluids, including gasoline, hydraulic fluids, glycol and oils.

Leakage and venting

In case LNG tanks are located in enclosed spaces for extended periods of time (e.g. for service), leakage and venting of natural gas (or other flammable substances) from the tank shall be dealt with properly to avoid the dangers due to releasing flammable substances in enclosed spaces.

Vehicle LNG tank(s) shall have a design hold time (build without relieving) minimum of 5 days after being filled net full and at the highest point in the design filling temperature/pressure range.

- **Annex 4 - Provisions on the approval of flexible fuel lines or hoses for CNG and hoses for LNG**

The purpose of this annex is to determine the provisions on the approval of flexible hoses for use with CNG or LNG.

This annex covers three types of CNG flexible hoses (a), (b), (c) and one type of LNG hose (d):

- a) High pressure hoses (Class 0);
- b) Medium pressure hoses (Class 1);
- c) Low pressure hoses (Class 2);
- d) LNG hoses (Class 5).

Annex 4H - Provisions on the approval of the electronic control unit

The purpose of this annex is to determine the provisions on the approval of the electronic control unit.

Electronic control unit

It can be any device which controls the CNG/LNG demand of the engine and establishes the cut-off of the automatic valve in case of a broken fuel supply pipe or in case of stalling of the engine, or during a crash.

The switching off delay of the automatic valve after stalling of the engine may not be more than 5 seconds.

The device may be equipped with an automatic ignition advance timing adjuster integrated in the electronic module or separated.

The device may be integrated with dummy injectors to permit a correct functioning of the gasoline electronic control unit during CNG/LNG operation.

The electronic control unit shall be so designed to operate at temperatures as specified in Annex 50.

Annex 4I - Provisions on the approval of the LNG heat exchanger – vaporizer

The purpose of this annex is to determine the provisions on the approval of the LNG heat exchanger – vaporizer.

The LNG heat exchanger – vaporizer can be any device made for vaporizing the cryogenic liquid fuel and deliver it as gas to the engine with gas temperature between -40 °C and +105 °C.

The material constituting the LNG heat exchanger - vaporizer which is in contact with the CNG when operating shall be compatible with the test CNG.

The part of the LNG heat exchanger - vaporizer which is in contact with the tank is regarded as Class 5.

It shall be so designed as to withstand a pressure of 1.5 times the working pressure (MPa) without leakage and deformation.

It shall be so designed as to be leak-proof (external) at a pressure of 1.5 times the working pressure (MPa).

The LNG heat exchanger – vaporizer has to comply with the test procedures for the Class 5.

It has to comply with the water jacket freezing test. Fill the part of the heat exchanger-vaporizer which normally contains an antifreeze solution, with water to normal capacity and expose it at -40 °C for 24 hours. Attach 1 m sections of coolant hose to the coolant inlet and outlet of the heat exchanger – vaporizer. Following the freezing conditioning, conduct an external leakage test at room temperature.

Annex 4J - Provisions on the approval of the LNG filling receptacle

The purpose of this annex is to determine the provisions on the approval of the LNG filling receptacle.

LNG filling receptacle

The LNG filling receptacle shall comply with the following requirements. The manufacturer of the receptacle may require a specific LNG nozzle type to be used.

The LNG filling receptacle test procedures

The LNG filling receptacle shall conform to the requirements of Class 5 and follow the test procedures with the following specific requirements:

- The non-metallic material constituting the LNG filling receptacle shall be compatible with LNG.
- The LNG filling receptacle shall be free from leakage at a pressure of 1.5 times the working pressure (MPa).

The filling unit shall withstand 7,000 cycles in the durability in terms of low temperature, room temperature and high temperature cycling.

Annex 4K - Provisions on the approval of the LNG pressure control regulator

The purpose of this annex is to determine the provisions on the approval of the LNG pressure

control regulator.

LNG pressure control regulator

The material constituting the regulator which is in contact with the LNG when operating shall be compatible with the test LNG. In order to verify this compatibility, it shall comply with the tests for Class 5.

Classification and test pressures

The pressure regulator that is in contact with the pressure of the LNG is regarded as Class 5.

The pressure control regulator shall be leak-proof with the outlet (s) of that part closed off.

It shall be so designed to operate at temperatures as specified in Annex 50.

Annex 4L - Provisions on the approval of LNG pressure and/or temperature sensor

The purpose of this annex is to determine the provisions on the approval of the LNG pressure and/or temperature sensor.

LNG pressure and temperature sensors

The LNG pressure and temperature sensors are classified in Class 5.

The LNG pressure and/or temperature sensor test procedures.

The LNG pressure and/or temperature sensor test procedures shall conform to the requirements of Class 5 and follow the test procedures in Annex 5 with the following specific requirements.

Insulation resistance test

This test is designed to check for a potential failure of the insulation between the LNG pressure and/or temperature sensor connection pins and the housing.

Apply 1,000 V DC between one of the connector pins and the housing of the LNG pressure and/or

temperature sensor for at least 2 seconds. The minimum allowable resistance shall be $> 10 \text{ M}\Omega$.

The material constituting the LNG pressure and temperature sensors which is in contact with the LNG when operating shall be compatible with the test LNG.

The LNG pressure and/or temperature sensor shall be so designed as to operate at temperatures as specified in Annex 5O.

The Class 5 part of the LNG pressure and temperature sensors shall withstand a pressure up to 1.5 times the working pressure (MPa), at the temperature corresponding to rated service pressure from the table in Annex 5O, at room temperature and at the maximum temperature from Annex 5O.

Annex 4M - Provisions on the approval of the natural gas detector

The purpose of this annex is to determine the provisions on the approval of the natural gas detector.

Natural gas detector

The material constituting the natural gas detector which is in contact with the natural gas when operating shall be compatible with the test gas.

The natural gas detector test procedures

It shall be so designed as to operate at temperatures as specified in Annex 5O.

Insulation resistance test

This test is designed to check for a potential failure of the insulation between the connection pins and the housing of the natural gas detector.

Apply 1,000 V DC between one of the connector pins and the housing of the natural gas detector for at least 2 seconds. The minimum allowable resistance shall be $10 \text{ M}\Omega$.

The natural gas detector shall comply with relevant electromagnetic compatibility (EMC) requirements according to Regulation No. 10, 03 series of amendments or equivalent.

Annex 4N - Provisions on the approval of the automatic valve, check valve, pressure relief valve, excess flow valve, manual valve and non-return valve for LNG applications.

The purpose of this annex is to determine the provisions on the approval of the automatic valve, the check valve, the pressure relief valve and the excess flow valve only for LNG applications.

The LNG automatic valve

The materials constituting the LNG automatic valve which are in contact with the LNG when operating, shall be compatible with the test LNG.

Operating specifications

The LNG automatic valve shall be so designed as to withstand a pressure of 1.5 times the working pressure (MPa) without leakage or deformation.

The LNG automatic valve shall be so designed as to be leak-proof at a pressure of 1.5 times the working pressure (MPa).

The insulation resistance test

This test is designed to check for a potential failure of the insulation between the two-pin coil assembly and the LNG automatic valve casing.

Apply 1,000 V DC between one of the connector pins and the housing of the automatic valve for at least 2 seconds. The minimum allowable resistance shall be 10 MΩ.

The LNG check valve

The materials constituting the LNG check valve which are in contact with the LNG when operating, shall be compatible with the test LNG. In order to verify this compatibility the procedure described in Annex 5D shall be used.

Operating specifications

The LNG check valve shall be so designed as to withstand a pressure of 1.5 times the working pressure (MPa) without leakage and deformation at cryogenic temperature.

The LNG pressure relief valve

The materials constituting the pressure relief valve which are in contact with the LNG when operating shall be compatible with the test LNG.

Operating specifications

The LNG pressure relief valve in Class 5 shall be so designed as to withstand a pressure of 1.5 times the working pressure (MPa) at cryogenic temperature with the outlet closed off.

The pressure relief valve and pressure relief device of Class 5 shall be so designed as to be leak-proof at a pressure of 1.5 times the working pressure (MPa) with the outlet closed off.

The LNG excess flow valve

The materials constituting the LNG excess flow valve, which are in contact with the LNG when operating, shall be compatible with the test LNG.

The LNG manual valve

The materials constituting the LNG manual valve which are in contact with the LNG when operating, shall be compatible with the test LNG. In order to verify this compatibility, the procedure described in Annex 5D shall be used.

Operating specifications

The LNG manual valve device in Class 5 shall be designed to withstand a pressure of 1.5 times the working pressure at cryogenic temperature. It shall be designed to operate at a temperature from -162 °C to 85 °C.

LNG manual valve device requirements

One specimen shall be submitted to a fatigue test at a pressure-cycling rate not exceeding 4 cycles a minute as follows:

Hold at -162°C or lower while pressured for 100 cycles between 0 and working pressure WP.

The LNG non-return valve has to comply with the test procedures for the Class 5 component.

Annex 4O - Provisions on the approval of the LNG fuel pump

The purpose of this annex is to determine the provisions on the approval of the LNG fuel pump.

LNG fuel pump requirements among others include:

- The materials constituting the LNG fuel pump which are in contact with the LNG when operating shall be compatible with the test LNG.
- The LNG fuel pump, in Class 5 shall be designed to operate at a temperature from -162 °C to 85 °C. The device shall comply with the test procedures for the Class 5 components.
- The LNG fuel pump shall be constructed in such a manner as to avoid LNG trapping.
- The LNG fuel pump shall be provided with pressure control device to maintain the pressure within the operating pressure range.

- **Annex 5**

Annex 5D - CNG/LNG compatibility test

A non-metallic part in contact with CNG/LNG shall not show excessive volume change or loss of weight.

Resistance to n-pentane according to ISO 1817 with the following conditions:

- a) Medium: n-pentane;
- b) Temperature: 23 °C (tolerance according to ISO 1817);
- c) Immersion period: 72 hours.

Requirements:

- Maximum change in volume 20 per cent;
- After storage in air with a temperature of 40 °C for a period of 48 hours the mass compared to the original value may not decrease more than 5 per cent.

Annex 50 - Operating temperatures

The operating temperatures shall be:

	<i>Engine compartment</i>	<i>Assembled on the engine</i>	<i>On board</i>
Moderate (M)	- 20 °C ÷ 105 °C	- 20 °C ÷ 120 °C	- 20 °C ÷ 85 °C
Cold (C)	- 40 °C ÷ 105 °C	- 40 °C ÷ 120 °C	- 40 °C ÷ 85 °C
LNG (L)	-162°C ÷ 105 °C	- 162 °C ÷ 120 °C	- 162 °C ÷ 85 °C

Note - the LNG (L) temperature is the temperature of the fluid inside the components; for surrounding temperatures use M or C. Since, for LNG, saturation temperature and pressure have a direct relationship as shown in the table below, higher minimum temperatures shall be allowed for LNG components based on the described test pressure.

Saturation	
Temperature [°C]	Pressure [barg]
-161.6	0
-152.5	1
-146.4	2
-141.7	3
-137.8	4
-134.4	5
-131.4	6
-128.7	7
-126.3	8
-124.0	9
-121.9	10
-119.9	11
-118.1	12
-116.3	13
-114.6	14
-113.0	15
-111.5	16
-110.0	17
-108.6	18
-107.3	19
-106.0	20
-104.7	21
-103.5	22
-102.3	23
-101.2	24

- **Annex 7 - Provisions on LNG identification mark for public service vehicles of categories M2 and M3, N2 and N3**

The sign consists of a sticker which shall be weather resistant.

The colour and dimensions of the sticker shall fulfil the following requirements:

Colours:

- Background: green
- Border: white or white reflecting
- Letters: white or white reflecting

Dimensions:

- a) Border width: 4 - 6 mm
- b) Character height: • 25 mm
- c) Character thickness: • 4 mm
- d) Sticker width: 110 - 150 mm
- e) Sticker height: 80 - 110 mm

The word "LNG" shall be centred in the middle of the sticker.

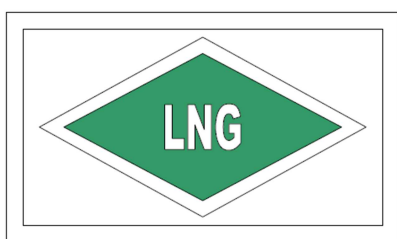


Figure 4-5 LNG identification mark

4.6.2 Other European regulations and standards under development

Engine emissions regulations for LNG HDVs

Work is currently in progress for a new UNECE regulation that will include retrofitted LNG HDVs³, which is expected to be included in UNECE R115, and new Euro V LNG HDVs, which are not yet covered by emissions regulations.

Gas quality / composition standards: Biomethane and LNG used as a vehicle fuel

The European Commission has mandated CEN to prepare standards for biomethane for use in transport & injection in natural gas pipelines (M 475). This mandate includes the requirement for a European Standard for a quality specification for biomethane to be used as a fuel for vehicle

³ Draft new Regulation on uniform provisions concerning the approval of specific LPG (liquefied petroleum gases) or NG (compressed and liquefied natural gas/bio-methane) dual fuel retrofit systems and dual fuel retrofitted engines to be installed in heavy duty applications – work carried by the UNECE DF Task Force.

engines. A specific Technical Committee called CEN TC 408 has been established to execute this mandate. Its work is currently in progress. LNG fuel composition has been added to the scope of CEN TC 408.

4.6.3 International regulations and standards under development

ISO/DIS 12617 → Liquefied natural gas vehicles – Connector for refuelling vehicles

Status: Under development by ISO/TC 22/SC 25. Enquiry stage, close of voting (2013-04-02). Target publication date: 2014-04-14.

ISO/DIS 12614 series (12614-1 to 12614-18) → Road vehicles – Liquefied natural gas (LNG) fuel system components

Status: Under development by ISO/TC 22/SC 25. Enquiry stage, close of voting (2013-04-18).

Part 1: General requirements and definitions (ISO/DIS 12614-1)

Part 2: Performance and general test methods (ISO/DIS 12614-2)

Part 3: Check valve (ISO/DIS 12614-3)

Part 4: Manual valve (ISO/DIS 12614-4)

Part 5: Tank pressure gauge (ISO/DIS 12614-5)

Part 6: Overpressure regulator (ISO/DIS 12614-6)

Part 7: Pressure relief valve (ISO/DIS 12614-7)

Part 8: Excess flow valve (ISO/DIS 12614-8)

Part 9: Gas-tight housing and ventilation hose (ISO/DIS 12614-9)

Part 10: Rigid fuel line in stainless steel (ISO/DIS 12614-10)

Part 11: Fittings (ISO/DIS 12614-11)

Part 12: Rigid fuel line in material other than stainless steel (ISO/DIS 12614-12)

Part 13: Pressure control regulator (ISO/DIS 12614-13)

Part 14: Differential pressure fuel content gauge (ISO/DIS 12614-14)

Part 15: Capacitance fuel content gauge (ISO/DIS 12614-15)

Part 16: Heat exchanger – vaporizer (ISO/DIS 12614-16)

Part 17: Natural gas detector (ISO/DIS 12614-17)

Part 18: Gas temperature sensor (ISO/DIS 12614-18)

4.6.4 Some aspects uncovered in the current regulations

LNG nozzles and receptacles

There is no European or International standard that ensures the compatibility of LNG nozzles and receptacles. There is ongoing work for the standardisation of a given LNG receptacle dimension (upcoming ISO Standard ISO/DIS 12617, which will then be incorporated in the UNECE R110 regulation), but this work does not cover the compatibility between nozzles and receptacles.

There are three main types of nozzles and receptacles: JC Carter, Parker Kodiak and Macrotech.

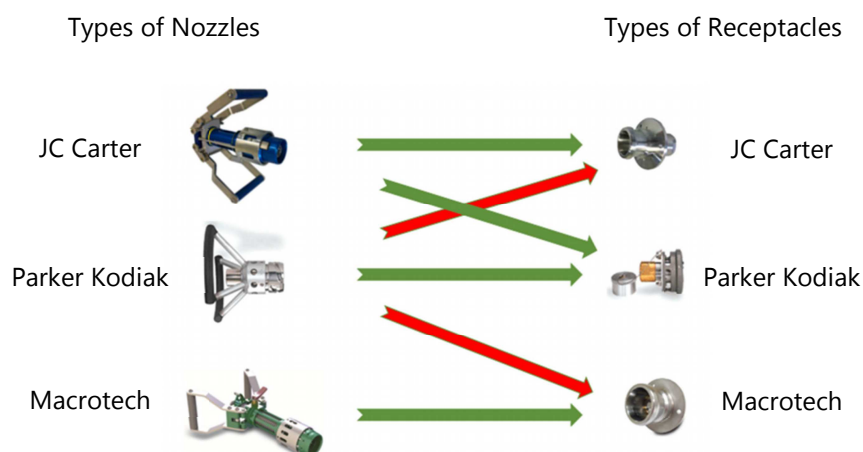


Figure 4-6 Main types of nozzles and receptacles. Source: JC Carter, Parker Kodiak and Macrotech

There are compatibility issues in two cases:

- Between Parker Kodiak nozzles and JC Carter receptacles; and
- Between Parker Kodiak nozzles and JC Carter receptacles.

On one hand, a Parker Kodiak nozzle requires a Parker Kodiak receptacle because it relies on Parker's unique twist clamping, whereas a JC Carter or a Macrotech nozzle can fill any receptacle. On the other hand, any nozzle can fill the Parker receptacle, whereas JC Carter and Macrotech receptacles can only be filled by JC Carter or Macrotech nozzles (JC Carter nozzles and Macrotech receptacles are compatible, as well as Macrotech nozzles and JC Carter receptacles). It is also important to note that "adaptors" between different types of nozzles and receptacles are illegal in the EU for safety reasons.

JC Carter nozzle is the de facto standard in North America and China. There are hundreds of JC Carter nozzles in service across the world. Macrotech and JC Carter receptacles (which are fully compatible with JC Carter nozzles) are the most common in North America and China. There is a lot of experience globally with the JC Carter nozzles connecting to the Macrotech receptacle.

Nearly all the LNG stations built in Europe in the recent years use JC Carter nozzles (and Macrotech for gas return). Parker Kodiak nozzles are used in some stations, almost exclusively in the UK and the

Netherlands.

Examples of other aspects that are not covered by the current European and International regulations and standards in force or under development

- Fuelling infrastructure operations including safety aspects in the refuelling operation of LNG vehicles (Dutch PGS 33 guidelines under development; Part 1 LNG truck fuelling).
- Weights and dimensions for LNG vehicles. Current situation:
 - o Dir 96/53/EC regulates weight restrictions in the EU Member States
 - o Derogations to Dir 96/53/EC are currently only proposed for electric battery trucks and hybrids, which are primarily focused on urban applications
 - o Some countries, regions and municipalities have their own rules and exemptions for LNG vehicles and NGVs more generally, but these rules and exemptions only apply in the territories themselves
- Maintenance facilities (workshops) handling LNG vehicles.
- Parking structures receiving LNG vehicles.

4.7 Summary of North American codes, regulations and standards

NFPA 52 → Vehicular Gaseous Fuel Systems Code – 2013

Applicability: NFPA 52 safeguards people and installations with requirements that mitigate the fire and explosion hazards associated with compressed natural gas (CNG) and liquefied natural gas (LNG) engine fuel systems and fuelling facilities.

Provisions cover the design, installation, operation, and maintenance of CNG and LNG fuel systems on all vehicle types--plus their respective compression, storage, and dispensing systems. This Code applies to all facilities with LNG storage in containers of 70,000 gallons or less.

Comments: Very good source of guidance for CNG, LNG and L/CNG vehicles and fuelling facilities.

NFPA 57 → Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code – 2002

Applicability: NFPA 57 shall apply to the design, installation, operation, and maintenance of liquefied natural gas (LNG) engine fuel systems on vehicles of all types, to their associated fuelling (dispensing) facilities, and to LNG to CNG facilities with LNG storage in ASME containers of 70,000 gal (265 m³) or less.

Comments: Main source of guidance for LNG vehicles but also fuelling facilities.

SAE J2343 → Recommended Practices for LNG-Powered Heavy-Duty Trucks – 2008

Applicability: Provides guidance for the construction, operation, and maintenance of LNG powered medium, heavy-duty vehicles and all LNG vehicles used for public transit or commercial applications.

Comments: Published by the Society of American Engineers (SAE). Primarily heavy truck recommendations but also some maintenance facility equipment and procedures.

DOT-FTA-MA-26-7021-97-1 → Design Guidelines for Bus Transit Systems Using Liquefied Natural Gas (LNG) as an Alternative Fuel (3/97)

Applicability: Transit Facilities but useful reference for other fleets.

Comments: FTA (Federal Transit Administration) Report - Not only references required codes (e.g. NFPA) but also suggests additional precautions and provides general information.

DOT-FTA-MA-90-7007-95-3 → Liquefied Natural Gas Safety in Transit Operations (3/96)

Applicability: Transit Facilities but useful reference for other fleets.

Comments: FTA (Federal Transit Administration) Report - Not only references required codes (e.g., NFPA) but also suggests additional precautions and provides general information.

ANSI NGV3.1-1995 → Fuel System Components for Natural Gas-Powered Vehicles

Applicability: Fuel system components for NGVs (excludes LNG components upstream of vaporizer)

Comments: Primarily for converted vehicles.

49 CFR 178.57 → Specification 4L welded insulated cylinders

Applicability: LNG vehicular fuel tank requirement called out in NFPA 57.

Comments: Option is meeting ASME Boiler and Pressure Vessel Code.

49 CFR 393.67 → Liquid fuel tanks

Applicability: Tanks containing or supplying fuel for the operation of commercial motor vehicles.

49 CFR 393.65, FMCSR → All fuel systems

Applicability: Commercial vehicles in interstate commerce.

Comments: DOT Federal Motor Carrier Safety Regulations. May have been adopted by states for intrastate application. Was not written with NGVs in mind but may be legally applicable.

ASME Boiler and Pressure Vessel Code, Section VIII (Pressure Vessels)

Applicability: Some sections applicable to LNG containers used on vehicles and in fuelling stations.

State level codes:

California Code of Regulations (CCR), Title 13, Div 2, Ch 4, Article 2

Applicability: Fuel systems using LNG in 13 CCR 935, CNG in 13 CCR 934

Comments: California vehicle requirements

California Code of Regulations (CCR), Title 8, Div 1, Ch 4, Subchapter 1

Applicability: CNG and LNG Storage Tanks

Comments: California fuel storage requirements

Texas Administrative Code, Title 16, Part 1

Applicability: LNG regulations in Chapter 14

Comments: Texas requirements

CSA B109-01 → Natural Gas for Vehicles Installation Code

Applicability: Canadian Std. Applies to “installation, servicing and repair of NG fuel systems on self-propelled vehicles.”

Other codes, standards and guidelines applicable to parking structures and repair garages for LNG vehicles

NFPA 88A → Standard for Parking Structures – 1998

Applicability: Open, enclosed, basement and underground parking structures

Comments: No special requirements for NGVs other than reference to NFPA 52 and 57.

NFPA 88B → Standard for Repair Garages

Applicability: Construction and protection of, as well as the control of hazards in, garages used for major repair and maintenance of motorized vehicles and any sales and servicing facilities associated therein

Comments: NGV requirements are also included in NFPA 30A.

NFPA 30A → Code for Motor Fuel Dispensing Facilities and Repair Garages - 2012

Applicability: Facilities dispensing both gaseous and liquid fuels at the same facility.

Comments: Includes requirements of old 88B on repair garages

International Fire Code (IFC) – 2012

Applicability: International fire code.

Comments: Check with local fire marshal on applicability.

Guideline for Determining the Modifications Required for Adding Compressed Natural Gas and Liquefied Natural Gas Vehicles To Existing Maintenance Facilities – Published by the Clean Vehicle Education Foundation – 2012

Applicability: This document looks at the modifications necessary for existing liquid fuel maintenance facilities to service both CNG and LNG vehicles.

Comments: The basic national codes are outlined and the rational and/or assumptions used to develop the codes are discussed in this guideline.

Technical Guideline for the Design and Operation of Facilities Used For Indoor Repair, Storage and Cargo Handling for Vehicles Fuelled by Compressed Natural Gas and Liquefied Natural Gas – Published by the Canadian Natural Gas Vehicle Alliance (CNGVA) – 2012

Applicability: This document is intended to be a reference guideline related to facility design and operations issues at indoor facilities used for the repair, storage or cargo handling of CNG and LNG-fuelled vehicles.

Comments: Canada does not currently have a code specifying the requirements for maintaining, storing, and/or cargo handling of natural gas-fuelled vehicles indoors.

In addition to these codes, standards and guidelines, local building codes and regulations vary by location so local officials always need to be consulted about the required NGV workshop upgrades.

4.8 Summary of Chinese regulations and standards

The National Clean Auto Leading Group is taking the lead to organize the setup of NGV regulations and standards. It decides the items (from gas supply, to refuelling station) for standards, and allocates relevant institutes or organizations to work out the standards. In terms of the NGV standards, China Automotive Technology and Research Centre (CATARC) had worked out a full set

of NGV standards, including CNG and LNG vehicles, fuelling stations, gas system, etc.

Up to now, nearly 400 types of gas vehicle (including chassis) produced by 60 enterprises are listed on national new product announcements of motor vehicles, covering bus, car, truck and municipal special vehicles, in which, 254 types are related to dual-fuel vehicles. In the last few years, the Chinese government and some of the industrial supervision departments have sped up pace to make legal and technical standards for NGVs. More than 50 national standards and industry standards have been implemented, divided in the following 8 sections: basic standard, vehicle, engine, special device, gas cylinder for vehicle, fuel quality, filling machine and filling stations. However, a lot of national standards or technical specifications still need to be amended and enforced, including specification for safety testing, cylinder testing, daily maintenance for gas supply system, etc..

The NGV standards system includes two parts: CNGV standards system and LNGV standards system. Most of the CNGV standards are also (at least partially) applicable to LNGVs since both vehicle types are partially similar and using the same components, at least after the vaporizer.

26 CNGV standards are currently in place. 16 CNGV standards (including 10 national standards and 6 industry standards) have been released by the automotive industry and 10 have been released by other industries.

CNGV standards released by the automotive industry:

- Basic standards:
 - o GB/T 17676-1999 → Identification marks ("Natural gas vehicle and liquefied petroleum gas vehicle Identification marks")
 - o GB/T 17895-1999 → Terms ("Natural gas vehicle and liquefied petroleum gas vehicle – Vocabulary")
- Vehicle standards:
 - o GB/T 26780-2011 → Collision safety requirements ("The safety requirement of fuel system for compressed natural gas vehicle in the collision")
 - o GB/T 23335-2009 → Approval program ("Natural gas vehicles – Engineering approval

- evaluation program")
- o GB/T 29125-2012 → Fuel consumption test ("Test methods for fuel consumption of CNG vehicles")
- Engine standards:
 - o QC/T 691-2011 → Mono-fuel vehicles ("Cars with natural gas single fuel engine technology conditions")
 - o QC/T 692-2011 → Dual-fuel vehicles ("Gasoline – natural gas dual-fuel engine technology conditions")
 - o GB 17691-2005 → Gas-fuelled positive-ignition engine emissions requirements ("Limits and measurement methods for exhaust pollutants from compression ignition and gas-fuelled positive ignition engines of vehicles (III IV V)")
- Refuelling equipment standards:
 - o GB/T 19236-2003 → Nozzles ("Fuelling nozzle for CNG dispenser")
 - o GB/T 19237-2003 → Dispensers ("Compressed natural gas dispenser for vehicle")
- Gas cylinder for vehicle standard:
 - o GB/T 18363-2001 → Filling receptacle ("Filling receptacle of CNG vehicle")
- Special device standards (6 items):
 - o Technical specifications for CNG special equipment
 - o Installation requirements
 - o Decompression regulator of CNG
 - o CNGVs special devices
 - o Electromagnetic valves
 - o High pressure pipes

CNGV standards released by other industries:

- Vehicle standards:
 - o GB/T 18437.1-2009 → CNGV retrofits ("The technical criterion of refitting for vehicle by using gas - Part 1: Compressed natural gas automobile")
 - o GB 19344-2003 → Gas supply system requirements and tests ("Technique requirement and test method of leaking-safety of gas supply system on using gas vehicle")

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- o GB/T 27876-2011 → Maintenance requirements ("Technical specification for the maintenance of compressed natural gas vehicle")
 - Gas standard:
 - o GB 18047-2000 → CNG ("Compressed natural gas as vehicle fuel")
 - Gas cylinder and parts standards:
 - o GB 17258-2011 → Steel CNG cylinders ("Steel cylinders for the on-board storage of compressed natural gas as a fuel for automotive vehicles")
 - o GB 17926-2009 → CNG cylinder valves ("Compressed natural gas cylinder valve for vehicle")
 - o GB 19533-2004 → Periodic inspection of steel CNG cylinders ("Periodic inspection and evaluation of steel gas cylinders for the on-board storage of compressed natural gas as a fuel")
 - o GB 24160-2009 → Composite CNG cylinders ("Hoop-wrapped composite cylinders with steel liner for the on-board storage of compressed natural gas as a fuel for automotive vehicles")
 - o GB 24162-2009 → Periodic inspection of composite CNG cylinders ("Periodic inspection and evaluation of hoop wrapped fibre reinforced composite gas cylinders with metal liners of compressed natural gas for automotive vehicles")
 - Refuelling stations standards:
 - o JB/T 10298-2001 (2009) → Compressors ("The natural gas compressor for the vehicle gas station")

Most of the LNGV standards refer to the CNGV standards. A lot of work on LNGV standards is currently ongoing or in the work plan.

- Basic standards: same as CNGV standards. LNG already covered by GB/T 17676-1999. GB/T 17895-1999 needs to be updated.
- Vehicle standards:
 - o QC/T 754-2006 → Specifications for LNG vehicle tests
 - o GB 18442-2001 → Cryo-insulation pressure vessels
 - o CNGV standards need to be adapted to include technical requirements of retrofit, test,

fuel leakage limit value and testing method for LNG vehicles.

- Engine standards: Technical specifications for LNG engines and diesel-LNG dual-fuel engines are in the work plan (CNGV standards need to be adapted). Other standards are the same as for CNGVs.
- Filling receptacle for vehicle standards: currently the same as LPGV cylinder standard. GB/T 18363-2001 (CNG filling receptacle standard) is being revised to include LNGV tanks.
- Fuel quality standards: LNG Characteristics standard.
- Refuelling infrastructure standards:
 - o GBT 20368-2006 → Production storage and handling of Liquefied Natural Gas (LNG)
 - o NB/T 1001-2011 → Technical standard for vehicle liquefied natural gas fuelling station
- Environmental standards: requirement is to be in compliance with the existing standards.
- Special device standards:
 - o QC/T 755-2006 → Technology requirements of special equipment for LNG vehicle (includes LNG tank with liquid level display, pressure gauge and other accessories; Vaporizer and Fuel refuelling system)
 - o GB/T 20734-2006 → Mounting requirements for LNG vehicle special equipment (gas storage system and vaporizer primarily)
 - o Standards for LNGV piping, safety valve, shut-off valve, cylinder valve, vaporizer, mixer, filling receptacle need to be created.